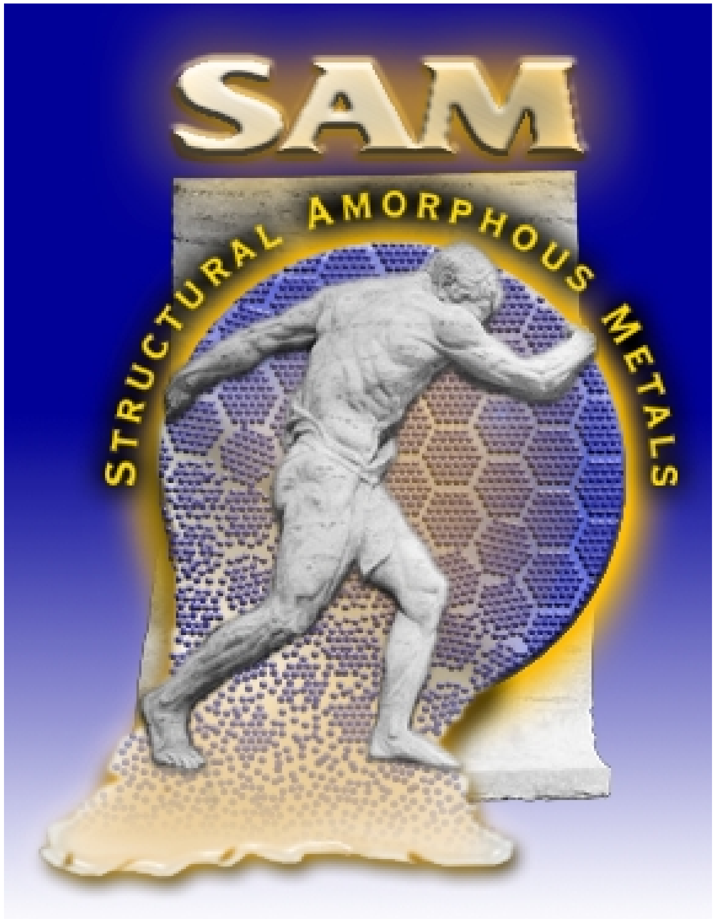


Structural Amorphous Metals

Leo Christodoulou

DARPA/DSO

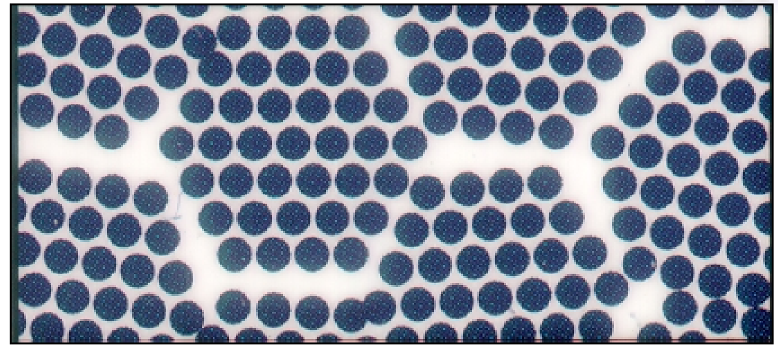
Compelling Opportunity

- **A totally new class of materials has been discovered with a radical combination of properties**
- **There are unique, compelling and enabling applications in several key DoD areas (e.g., ship hulls, aircraft structures, penetrators, etc.)**
- **DARPA will have a program to develop the science and technology of this field, and demonstrate its utility in example challenge problems**

Amorphous Metals are Fundamentally Different from Conventional Metals

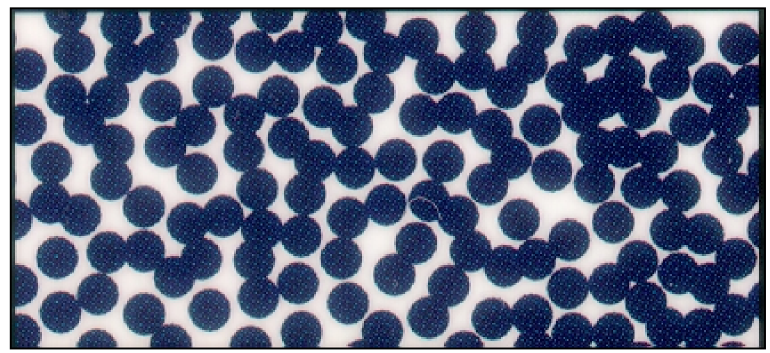
Crystalline (Normal) Metals

- ***Long-range order***
- ***Grain boundaries***



Amorphous Metals

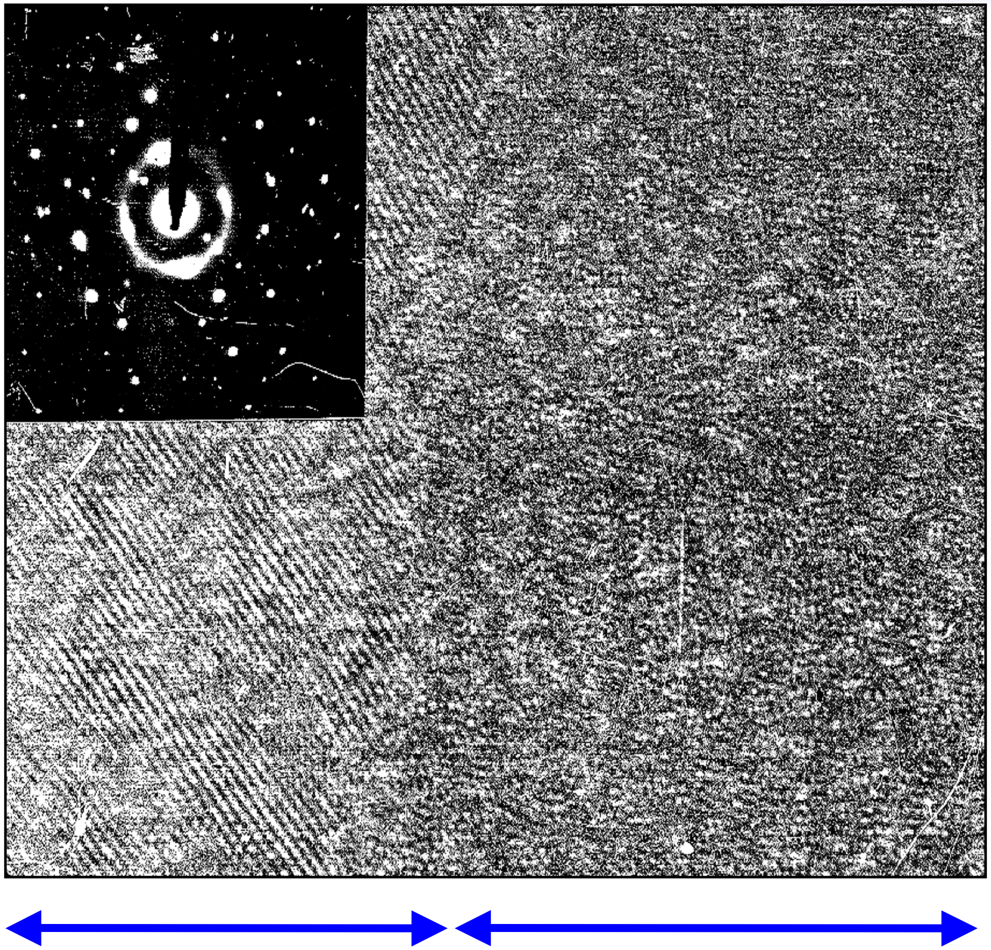
- ***NO long-range order***
- ***NO grain boundaries***



Amorphous materials exhibit unique properties

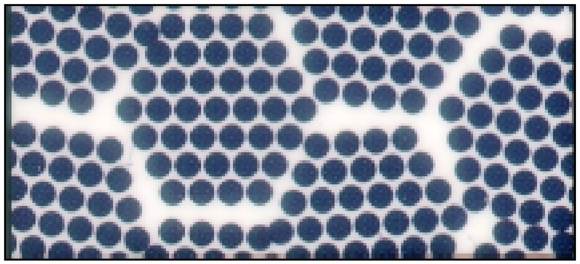
Atomic Arrangement in Crystalline and Amorphous Metals

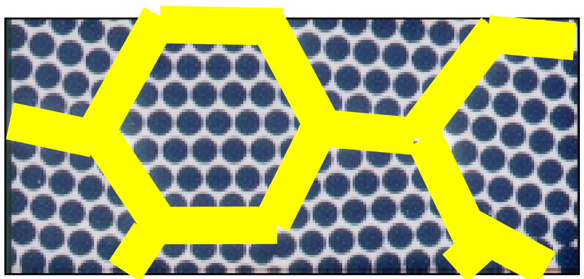
- **Micrograph shows:**
  - ➢ Interface between amorphous and crystalline metal
  - ➢ Atomic planes of crystalline metal
  - ➢ Random arrangement of amorphous material
  - ➢ Diffraction information



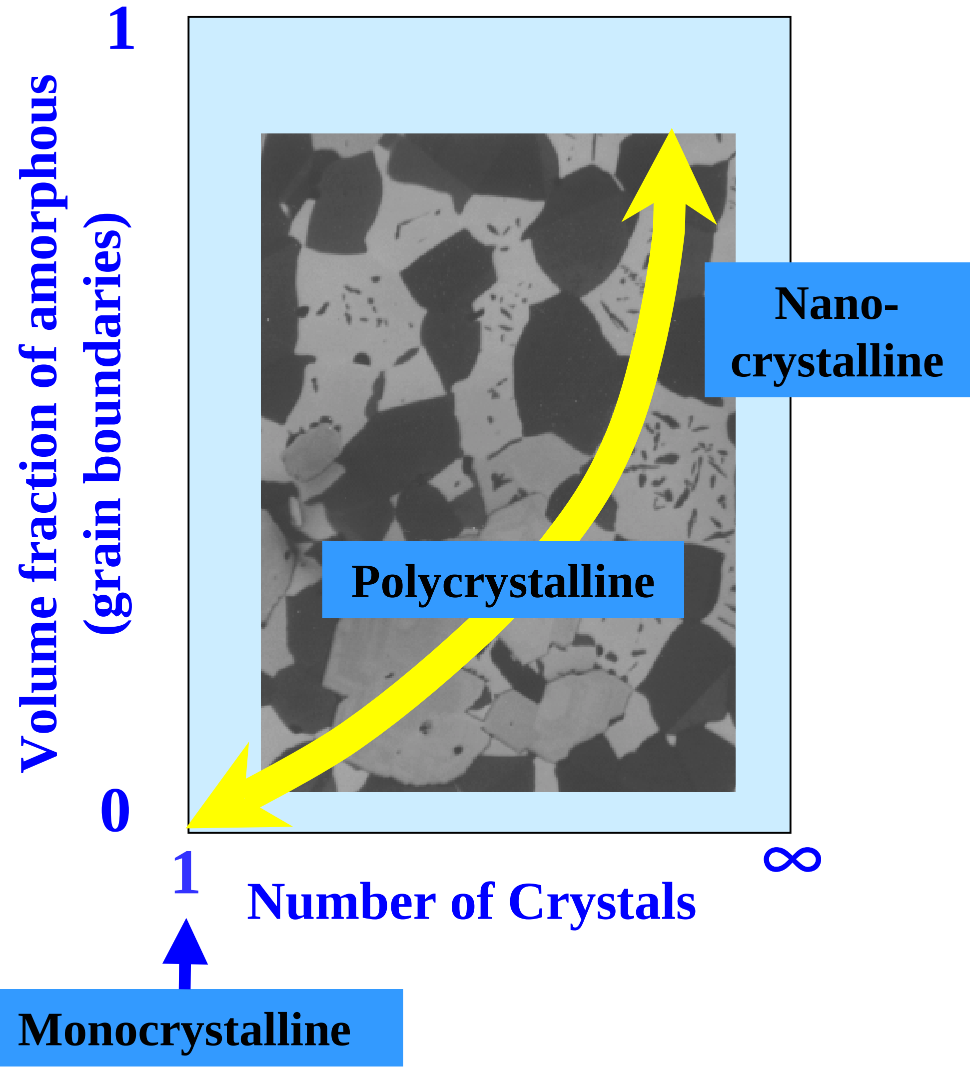
Since Their Discovery Metals have Relied on the Same Microstructural Constituents for their Properties

Polycrystalline



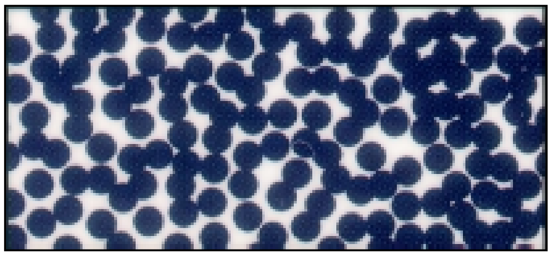


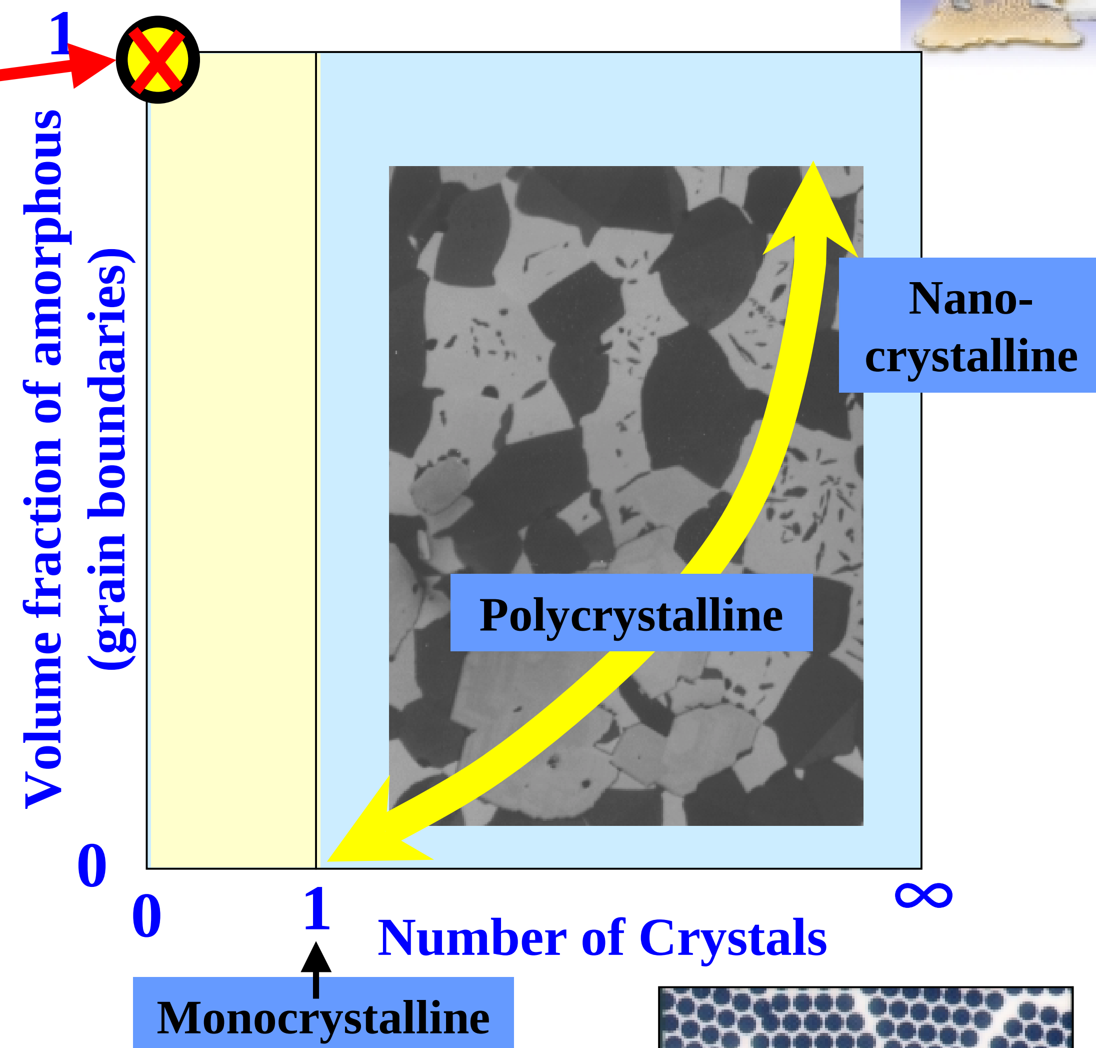
- Intersections of grains (grain boundaries) can be considered as “amorphous.”
- Changes in grain size change the volume fraction of amorphous content

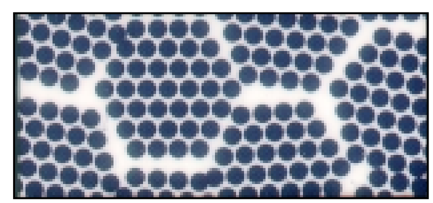


Structural Amorphous Metals Are New-to-the-World

Amorphous



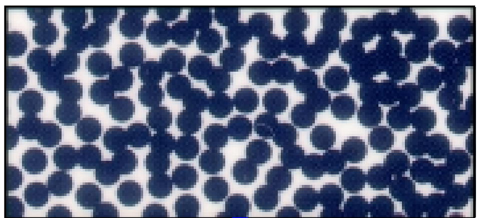




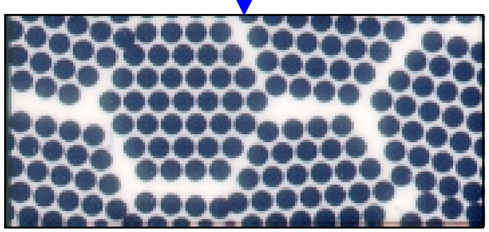
- Amorphous Metals are NOT confined by limitations of crystalline materials
- Such an opportunity has NOT previously existed for structural materials.

Transformations from the Amorphous to the Crystalline State Offer Unprecedented Materials Design Freedom

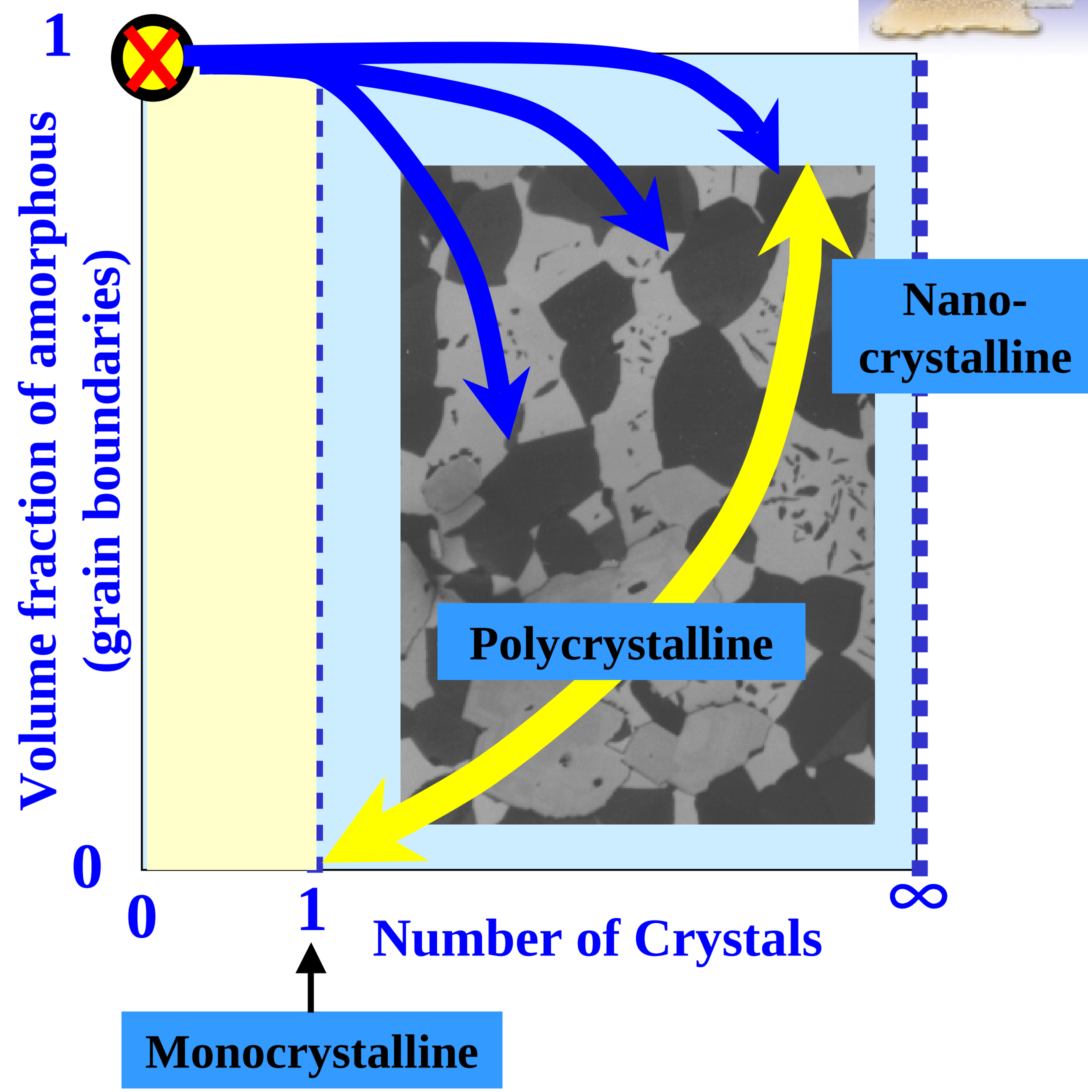
- Short-range order
- NO grain boundaries



Transition path could be of **CRITICAL** importance

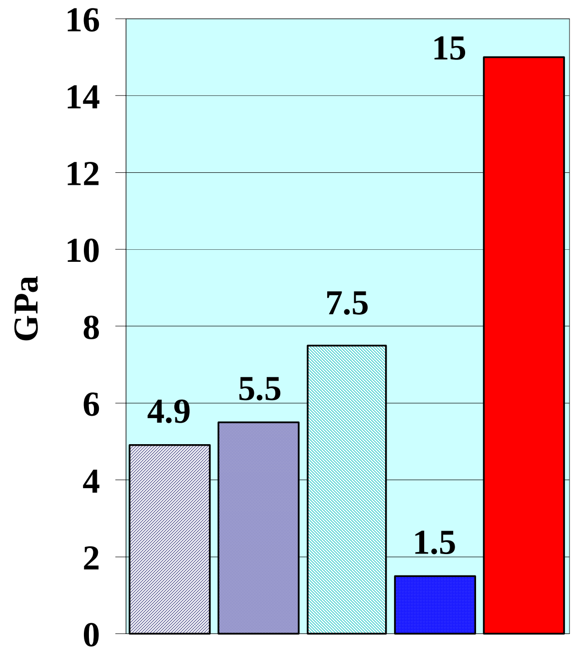


- Long-range order
- Grain boundaries

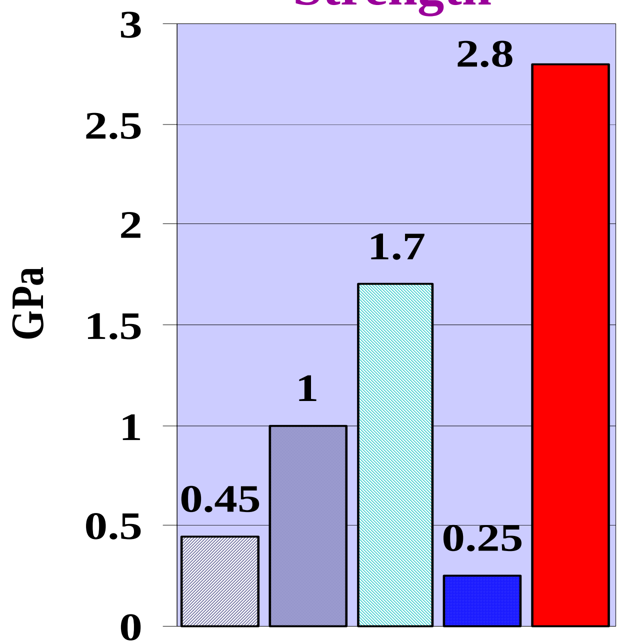


Why Amorphous Metals?

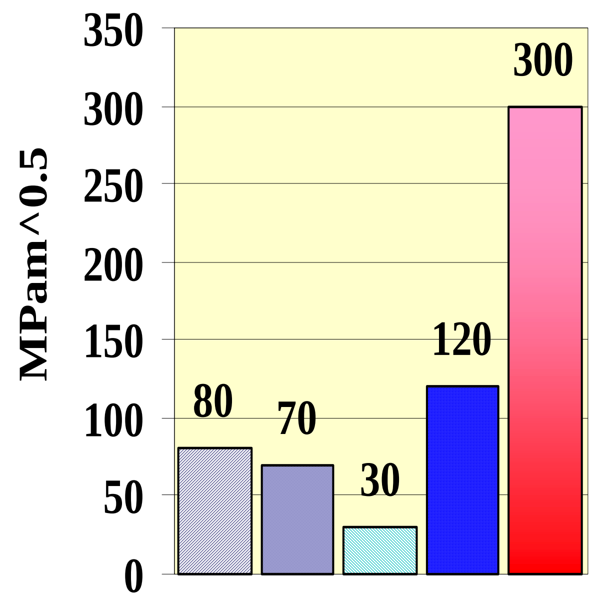
Hardness



Strength



Fracture Toughness



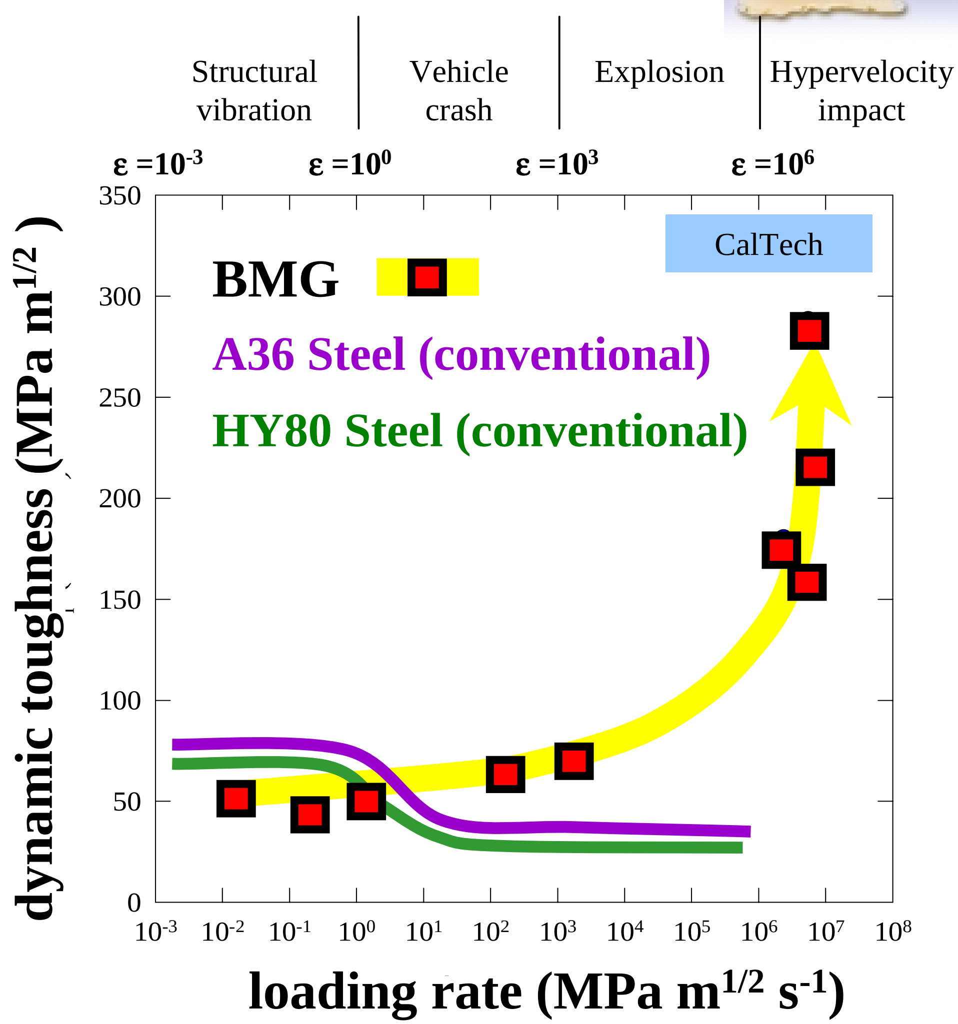
Steels

Carbon
High Strength
Tool
Stainless
Amorphous

Amorphous Metals are in a Class of their Own!

New-to-the-World Structural Materials: Unexpected Strain Rate Response in SAM

- **Dynamic toughness of SAM is <u>EXACTLY</u> the opposite of conventional materials -- toughness increases with strain rate**
- **<u>Speculate</u> that combination of high strength, hardness and dynamic fracture behavior will translate into useful naval and other structures**



Wear and Corrosion

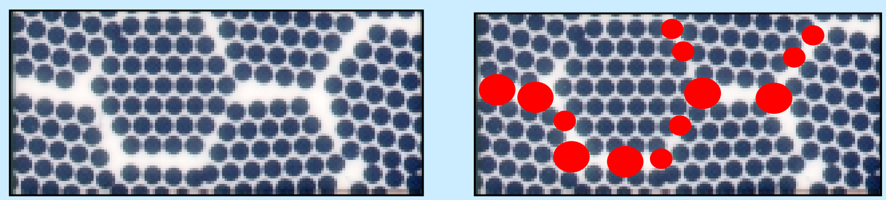
Amorphous Materials:

- Do NOT have grain boundaries (no corrosion initiation sites)
- Exhibit high wear resistance (better than Si_3N_4)
- Are damage tolerant

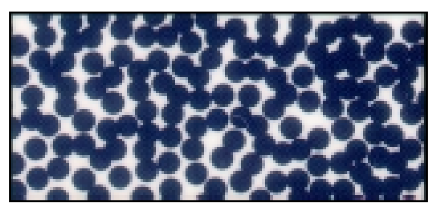
Challenge Problem:

Environmental conditions, e.g., marine environments, often induce degradation of properties due the presence of discontinuities within the material microstructure

Crystalline Localized Corrosion



Amorphous Steel



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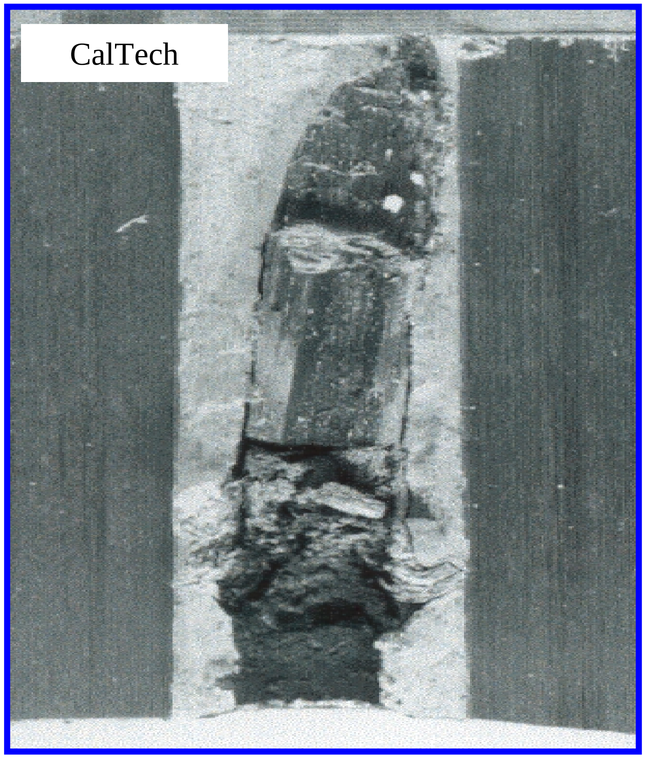
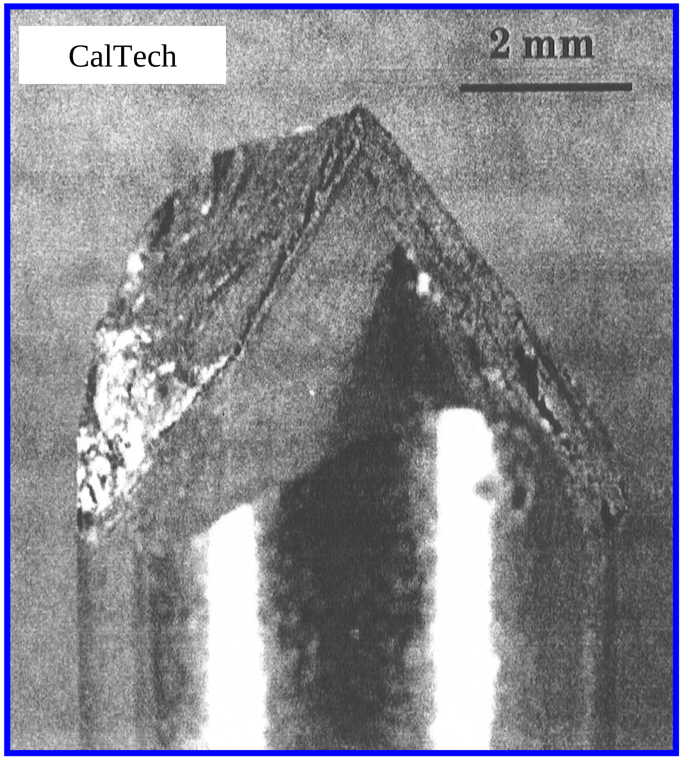
Amorphous Metals as New Penetrator Materials

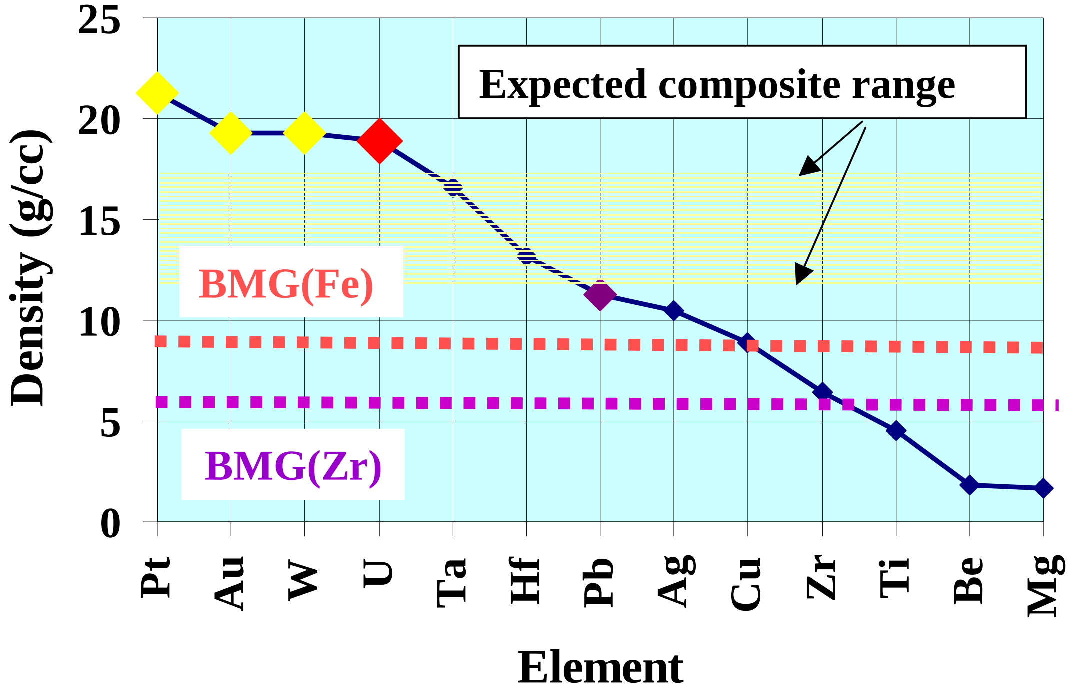




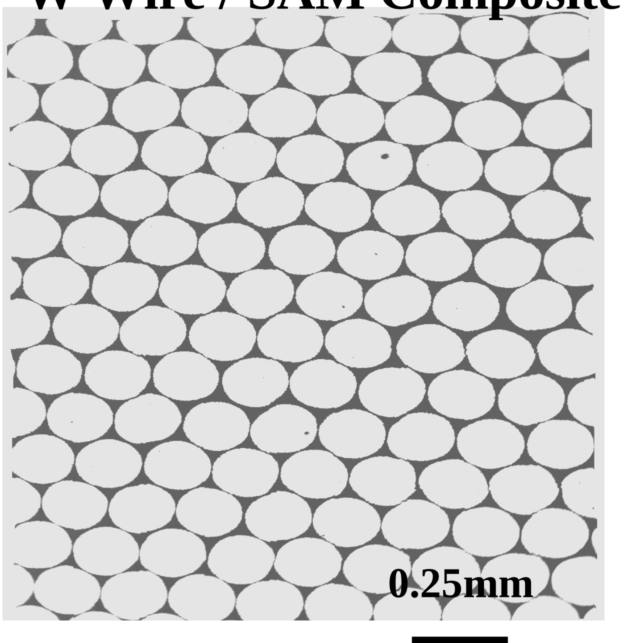
SAM materials known to exhibit self sharpening behavior

Penetrator Materials:
Amorphous Metals Provide New Options

Need control of strength, toughness, elongation, density and self-sharpening behavior.



W Wire / SAM Composite



W V_f=80%, ρ =16.8 g/cc

To achieve high density SAM must be turned into a composite.

ρ_{DU} = 18.9 ρ_{BMG}= 5.9-8.0g/cc. Tungsten is the obvious choice

Monolithic SAM may be sufficient in some applications.